Description of High Priority Technical Needs for MNA/EPR Project for Chlorinated Solvents

This attachment to the RFI includes the list of high priority technical needs for this project, a brief description of each need and the minimum associated experience required for the interested party.

Central to the Monitored Natural Attenuation (MNA) and Enhanced Passive Remediation (EPR) of Chlorinated Solvents Project is an integrated portfolio of research studies. The selected studies will be based on a group of 16 technical targets that have been identified to enhance the understanding and implementation of MNA and EPR. Field and applied research studies are strongly emphasized in this program. Nonetheless, the research efforts can be field or laboratory based, dependent on the technical target(s) being investigated. To facilitate the work, the Department of Energy Savannah River Site has identified several available field research sites, "testbeds," with chlorinated solvent contaminant plumes present at varying concentrations, plume geometries, and biogeochemical conditions. Access to and data from these sites will be available for field research proposed in response to the RFI. These research efforts are to last no more than 18 months with a follow-on 4-month period for data evaluation and report writing.

The research studies are for applied research and the results are to directly address one or more of the high priority technical targets. Research concepts that creatively address more than one of the targets and studies that incorporate data from a broad spectrum of sites are specifically desired. The portfolio of research studies, when completed, will support development of a technical guidance document that will serve as a resource to those who implement and regulate MNA remedies. The technical guidance document will be completed in January 2006. The research studies are expected to be in the cost range of $50K to $75K. Larger awards, up to $150K, will be made for meritorious research concepts that address multiple targets and integrate the results in a compelling manner.

General Qualifications

Interested organizations, or teams of organizations, must have a minimum of 3 years experience in the technical area in which they would like to participate. To support the research concept, the team must: 1) document the nature and scientific basis of the concept and how it addresses the high priority target(s), 2) document the capabilities of the organization to perform the work in terms of expertise and infrastructure, and 3) document the capability of the organization to credibly interpret and report results. Organizations who can leverage existing basic science research and accelerate the transition of the concept into application are encouraged to express interest. Personnel interested in participating who would need to conduct work at any of the four testbeds must be U.S. citizens. Additional qualifications, as appropriate are provided in the technical target descriptions below.

Required Information in Submitting Potential Offeror Capabilities:

The information required, from each potential offeror, is a capabilities and qualification statement that includes: a. A discussion of the respondent's past experience in the technical area the respondent is interested in targeting, including a list of contracts/subcontracts, dates of performance, contract value and a brief description of the quality of performance of these contracts. b. A brief description of the respondent's staffing, facilities, and all other resources necessary for conducting the proposed work in the technical area the respondent is interested in targeting. c. A demonstration of the respondent's understanding of the MNA/EPR project as evidenced by: (1) Describe what the respondent believes to be the unique challenges required to address the technical area the respondent is interested in targeting. (2) Provide a brief preliminary description of how the respondent will structure the research study to deal with these challenges. This statement should be no more than 5 pages (8.5" x 11") in length. Response should be provided in a narrative format with graphics, as appropriate, using Microsoft Word or PDF. Font size should be no smaller than 12 point. (3) WSRC will evaluate the submitted capability and qualification statements by considering the following: a. The depth and relevance of experience and past performance history. b. The adequacy and availability of necessary staffing, facilities, and other resources for conducting the research studies. c. The discussion of the key challenges identified for the technical area the respondent is interested in targeting and the approach in dealing with these challenges.

Technical Targets

To move MNA/EPR forward, we are interested in focused research in the following general topic areas:
1) Direct measures of Attenuation Mechanisms
2) Strategies to support characterization and monitoring
3) Tools to support characterization and monitoring
4) Use of passive or semipassive enhancements to MNA
Within these general topic areas, 16 specific technical targets have been established. These targets are listed (Table 1) and then briefly described below.

Table 1. High Priority Technical and Implementation Targets Recommended for DOE MNA/EPR Alternative Program

Direct measures of Attenuation Mechanisms
a) Develop advanced bioassessment tools for determining ongoing and potential microbial processes at different sites
b) Develop field scale correlations between species, functional genes, and degradation rate and potential
c) Conduct further research on oxidative and reductive processes
d) Develop direct measures and indicators for abiotic attenuation mechanisms
Strategies to support characterization and monitoring
e) Develop a scenario-based framework to support characterization monitoring and modeling decisionmaking.
f) Develop specific alternative monitoring configurations to collect data during system performance monitoring stage
g) Improve integration of modeling into MNA evaluation and implementation
h) Improve reaction forms and include variable linear equilibrium partitioning coefficients within analytical models.
Tools to support characterization and monitoring
i) Develop threshold and binary monitoring devices and strategies for long-term monitoring
j) Remote sensing of a parameter(s) that can be related to system performance
k) Develop spectroscopy methods (IR and other optical methods) to measure critical MNA parameters
l) Develop improved dissolved oxygen measurement approaches
m) Develop methods to measure flux more directly than traditional methods (groundwater and contaminant flux).
n) Samplers that integrate over distances and volumes
Use of passive or semipassive enhancements
o) Microbiology – Bioaugmentation
p) Modifying Large-scale Hydrology

Technical Target a. Develop advanced bioassessment tools for determining ongoing and potential microbial processes at different sites, including reductive processes (Dehalococcoides, etc.).
The objective of this target is the direct measure of a critical microbial capability that enables MNA at a chlorinated solvent site. The anticipated outcome is the ability to provide direct measures of degradation rates that are occurring within a plume, verification/monitoring of specific processes spatially and temporally, and to predict potential of various processes (e.g., downgradient of a existing source or plume, such as at potential discharge points). Achieving this target will require the development or verification of methods or protocols to determine the current and potential ability of indigenous subsurface

microorganisms to degrade chlorinated solvents via various microbial degradation processes, including reductive process (e.g., *Dehalococcoides*).

As there is considerable information on *Dehalococcoides*, we anticipate that it will be used as a test microorganism during the development of this target objective. Therefore, in addition to the general qualifications, interested parties shall have demonstrated experience working with this microorganism, its associated cultures, suitable facilities for the growth and culturing of anaerobic microorganisms, and ability to conduct microcosms. Interested parties should demonstrate familiarity and ability to apply molecular techniques to evaluate, assess the composition, and quantify genes of *Dehalococcoides* and associated microorganisms. Furthermore, we anticipate that DNA microarrays will be critical to identify functional genes and their response to environmental conditions, therefore, interested parties must be able to demonstrate the ability of using DNA microarrays to assess *Dehalococcoides* and associated microorganisms, and ideally already have developed initial microarrays containing genes from cultures containing *Dehalococcoides*. Interested parties would ideally be able to leverage funds provided in a contract award, or use the award to further advance work already completed.

Technical Target b. Develop field scale correlations between species, functional genes, and degradation rate and potential.
Key components of this effort are: (1) identification of unique gene sequences of various microorganisms associated with key biodegradation process; (2) identification of key functional genes; (3) develop correlations between unique gene sequences for microorganisms and/or functional genes with specific environmental conditions through laboratory and field studies; (4) assess factors that would bias the application of these molecular tools; (5) conduct field tests of the molecular tools (which may require bioaugmentation with *Dehalococcoides*).

As there is considerable information on *Dehalococcoides*, we anticipate that it will be used as a test microorganism during the development of this target objective. Therefore, interested parties shall have demonstrated experience working with this microorganism, its associated cultures, suitable facilities for the growth and culturing of anaerobic microorganisms, and ability to conduct microcosms. Interested parties should demonstrate familiarity and ability to evaluate, assess the composition, and quantify genes of *Dehalococcoides* and associated microorganisms. Interested parties would ideally have access to samples and data from a large number of field sites and would be able to leverage funds provided in a contract award, or use the award to further advance work already completed.

Technical Target c. Conduct further research on oxidative and reductive processes.
This additional research includes:

a) Basic research to investigate possible microorganisms other than Dehalococcoides-like microorganisms that may be involved in complete reductive dechlorination.

b) Identification of organisms involved in oxidative processes.

c) Determine the relative contribution of anaerobic oxidation in a site's natural attenuation capacity.

d) Determine the organisms involved in fermentative processes.

e) Identification of additional unique gene sequences that can be used to identify key microbial species involved in the degradation of chlorinated solvents.

Interested parties shall have demonstrated experience working with both anaerobic and aerobic cultures and performing field and microcosm testing for organisms in chlorinated solvent contaminated sediments.

Technical Target d. Develop and/or apply Direct measures and indicators for abiotic attenuation mechanisms.
The recent scientific literature suggests that abiotic reduction of chlorinated solvents is active at many sites. Developing a more direct method of determining the rate and extent of abiotic degradation would allow this process to be explicitly incorporated into MNA and facilitate regulatory and stakeholder acceptance. Key components of this effort are (1) to develop direct methods to measure the abiotic attenuation mechanisms,

and (2) conduct tests to provide evidence that the results of these methods can be used to establish capacity as well as provide concentrations.

Technical Target e. Scenarios based framework to support characterization monitoring and modeling decision-making.
The concept is to develop a framework to help define the multiple lines of evidence approach discussed in the 1998 EPA *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater*. The purpose is to develop a tool, similar to a taxonomic key used in biology, that will help the people investigating and implementing MNA make decisions for their specific site that will lead to efficient use of time and funding.

Interested parties shall have demonstrated experience in evaluating monitored natural attenuation at multiple sites (at least 25) with varying hydrogeologic and geochemical conditions.

Technical Target f. Develop specific alternative monitoring configurations to collect data at substantial cost savings during system performance monitoring stage.
Key components of this target are (1) to validate and compare the alternative monitoring configurations to baseline sampling and (2) to determine if integrating and flux type measurements are viable to evaluate the global health of a MNA system. One example of alternative monitoring configurations is use of horizontal wells to replace several vertical wells.

Technical Target g. Improve integration of modeling into MNA evaluation and implementation process.
The efficiency of monitored natural attenuation can defined as a mass balance between contaminant loading and the natural attenuation capacity of ground-water systems. This conceptualization can be quantified using numerical solute-transport models, which are based on the principle of mass balance. Of particular interest are models capable of simulating contaminant loading (i.e. NAPL dissolution, desorption,) in addition to contaminant attenuation. Improved formulations for incorporating attenuation mechanisms in addition to dispersion, reversible sorption, and biodegradation are of particular interest. These formulations might include adding irreversible/variable partitioning sorption processes and contaminant removal/transformation by plants to the overall natural attenuation capacity of a system. Also of interest would be a) guidance to assist the practitioner to decide when to use numerical modeling in evaluating and implementing MNA and b) address methods to deal with uncertainties inherent in numerical models as it relates to the MNA processes associate with chlorinated solvents. In all cases, investigations associated with models must be in alignment with the concept of balancing contaminant loading and attenuation capacity, and addressing this in terms of loading (mass/time).

Interested parties shall have demonstrated experience in model development associated with processes representative of those that contribute to monitored natural attenuation of chlorinated solvents.

Technical Target h. Improve reaction forms and include variable linear equilibrium partitioning coefficients within analytical models.
Non-equilibrium/irreversible sorption processes are an important component of natural attenuation capacity in many ground-water systems. However, present mathematical formulations of these processes commonly rely on reversible/equilibrium considerations. Improved methods/formulations of non-equilibrium/irreversible sorption processes with the goal of improving estimates of natural attenuation capacity, and the inclusion of these formulations in analytical or numerical modeling approaches is of particular interest.

Interested parties shall have demonstrated experience in model development associated with processes representative of those that contribute to monitored natural attenuation of chlorinated solvents.

Technical Target i. Develop threshold and binary monitoring devices and strategies for long-term monitoring.
The purpose is to identify tools that will provide an inexpensive method to monitor system parameters over an extended period of time. The central idea is these sentinel monitoring strategies would indicate that the

system performance has changed in a "negative" way. Thus, triggering the need to conduct more detailed or sensitive sampling. Examples of sentinel monitoring systems are threshold and binary sensing systems.

Interested parties shall have demonstrated experience in developing and deploying field hardened sensors and evaluating the performance of these sensors.

Technical Target j. Remote sensing of a parameter(s) that can be related to contaminant concentration or a measure of system impact from contamination
Measurement of these type parameters has been identified as potentially valuable for systems where large-scale water balance and similar controls are central to performance. A key component of this target is to validate that measuring these parameters is a representative measure of system performance.

Interested parties shall have access to remote sensing data and have demonstrated experience in developing field scale interpretations based on such data.

Technical Target k. Develop and or/apply spectroscopy methods (IR and other optical methods) to measure critical MNA parameters
Recent advances in IR sources and detectors may make this spectroscopic chemical speciating technique viable for long term applications for monitoring chlorinated organics. A key component of this technical target will be to verify that IR absorption sensors will be viable as permanently deployed or disposable sensors. Important factors to demonstrate in the field are good sensitivity and resolution, and stable response over time.

Interested parties shall have demonstrated experience in developing and deploying field hardened sensors and evaluating the performance of these sensors.

Technical Target l. Improve systems to measure dissolved oxygen
There was specific emphasis on the need for an improved dissolved oxygen measurement. One example might be a sensor based on the use of optical fluorescence. The main reason identified for needing an oxygen sensor is that present day field methods do not provide a reliable, accurate measure of dissolved oxygen in the system. Thus, a key component of this target will be to validate that an optical fluorescence based oxygen sensor (or other alternative) provide reliable, accurate data of dissolved oxygen in the range useful for MNA of chlorinated solvents in subsurface systems.

Interested parties shall have demonstrated experience developing and deploying field hardened sensors and evaluating the performance of these sensors.

Technical Target m. Develop methods to measure flux more directly than traditional methods (groundwater and contaminant flux).
There are a range of devices for estimating flux by comparing tracer dilution and concentration, micro pump tests and the like. A key component of this target is to develop and validate a direct measure of flux that provides information on a "site-wide" scale versus point measurements. Other concepts include dynamic flux measurements associated with the rising and falling stream and the like. Flux measurements that integrate over time and/or over larger cross-sectional areas may be useful.

Interested parties shall have demonstrated experience field characterization methods and hydrogeology.

Technical Target n. Samplers that integrate over distances and volumes.
Current sampling often requires a large number of monitoring wells that provide data at one location. These "point" samplers are expensive to operate because of the number required and there is uncertainty about what is happening between the wells. In some settings, integrating samplers provide an opportunity to decrease the number of analyses while increasing confidence that a plume is not being missed. One example would be flexible liner (e.g., FLUTe) based sampling that provides reliable information on the presence of DNAPL at a high resolution over a long vertical distance. A key component of this target is to develop other integrating samplers or indicators to provide characterization data to access whether natural

attenuation processes are occurring. Other examples might include long path length and open path length monitoring, subsurface geophysics, and similar integrating methods.

Technical Target o. Microbiology – Bioaugmentation.

One stumbling block to complete biodegradation of TCE and PCE is the "stalling" at cis-DCE. Results from several basic research programs have shown that introduction of cultures of *Dehalococcoides* in an anaerobic environment will, once established, allow the degradation process to continue to ethene. However, at many DOE sites, cis-DCE migrates or discharges in to aerobic groundwater or surface waters where it can persist. The objective of this target is to evaluate if bioaugmentation with cultures containing appropriate aerobic degrading bacteria is a viable approach to enhancing the natural attenuation of cis-DCE without further intervention (i.e., need to add additional nutrients to maintain activity). Key components of this effort include; (1) selection and optimization of cultures for inoculation in the field; (2) establishing kinetics, enzymatics, and tolerance ranges of the aerobic cis-DCE degrading bacteria; (3) develop molecular probes for monitoring the spread and persistence of the introduced aerobic cis-DCE degrading bacteria; and (4) conduct microcosms and field demonstrations, and validation of bioaugmentation with said bacteria.

Interested parties shall already possess cultures or isolates that aerobically degrade cis-DCE, demonstrated experience in the isolation and characterization of microorganisms or cultures able to metabolize chlorinated solvents, demonstrated experience to conduct microcosm studies with chlorinated solvents, and facilities to characterize microbial kinetics and enzymes and to allow growth of cultures to sufficient volume to use in field pilot tests. Interested parties would ideally be able to leverage funds provided in a contract award, or use the award to further advance work already completed.

Technical Target p. Modifying Large-scale Hydrology.
Most of the concepts for enhanced passive remediation rely on increasing the attenuation capacity of the system so that it is sustainable and exceeds the contaminant loading. An alternative concept is to reduce the contaminant loading so that the natural attenuation capacity of the site is sufficient. This alternative concept is the basis for this technical target. Potentially viable large-scale hydrology enhancements are:

a) Bypass of upgradient water.
b) Decrease infiltration throughout plume by increasing runoff or increasing evapotranspiration.
c) Decrease mass discharge from the source(s).
d) Bypass of competing electron acceptors.

The key component of this technical target is to provide evidence that hydrology integrates with MNA/EPR.

Interested parties shall have demonstrated field experience in hydrogeology and engineering.